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COMPLETE SPECIFICATION

Improvements relating to Variable Electrical Phase-Shifters for Circularly Polarised Waves

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63 Aldwych, London, W.C.2, England do hereby declare the invention, (Communicated by International Telephone and Telegraph Corporation, a Corporation of the State of Maryland, United States of America, of 67 Broad Street, New York, 4, New York, United States of America) for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to microwave phase shifters and more specifically to high speed continuous rotary waveguide phase shifters utilising spiral conductors as circularly polarised antennas.

In many microwave system applications, waveguide phase shifters are needed, generally, for such applications as shifting the angular position of an antenna beam. Heretofore various means and methods of shifting the phase of an output microwave with respect to the input wave have been proposed. The majority of such means have been primarily voltage devices with the disadvantage that the output power transmitted to the load had to be kept very small so as not to disturb the phase relations in the circuit.

In United States Patent Specification No. 2,530,818, there is described a variable phase-shifter comprising a hollow waveguide-section enclosing respectively at opposite ends two pairs of dipole antennas, the dipoles of each pair being set at right-angles, with arrangements for rotating one pair about the axis of the waveguide-section. High frequency waves are supplied to one pair of dipoles in such manner that they radiate circularly polarised waves which are picked up by the other pair of dipoles, the rotation causing a continuous phase-shift.

According to the present invention, this type of arrangement is improved by replacing the rotatable pair of dipole antennas by an antenna in the form of a spiral conductor arranged with its plane normal to the axis of the waveguide section.

The invention will be described with reference to the accompanying drawing, in which:

Fig. 1 shows a longitudinal cross-sectional view of an embodiment of the invention;

Fig. 2 shows a plan view taken along the line 2—2 of Fig. 1; and

Fig. 3 shows a longitudinal cross-sectional view of a receiving antenna that may be used in place of the output probe arrangement shown in Fig. 1.

Referring to Figs. 1 and 2 of the drawing, a microwave phase shifter in accordance with this invention is shown in which a source of microwave energy is applied to the phase shifter through a coaxial connector 1. The outer conductor 1a of the input coaxial connector 1 is joined to one end of a section of circular waveguide 2. The inner conductor 3 of the coaxial connector 1 is coupled to a sleeve 3a which supports a rotatable shaft 4 by means of a pair of bearings 5. A sleeve 4a is coaxial to a sleeve 6 to form a radio frequency choke 6a, adjacent the shaft 4 at the end of the sleeve 6. The shaft 4 extending beyond the end of the sleeve couples energy from inner conductor 3a to a spiral conductor 7 carried by a disc 10 of dielectric material as an input spiral antenna 8. While conductor 7 is shown to be ribbon-like in cross-section it may of course be round or any other shape desired. The ribbon-like shape is to be preferred where it is applied to a disc of dielectric material such as where printed circuit technique is employed. Where the conductor 7 is sufficiently sturdy, either of round, ribbon or other cross-sectional shape, the dielectric disc may be omitted. The spiral antenna 8 is adapted to launch a circularly polarised wave for propagation along the circular wave guide 2 in accordance with the H_{11} mode. The waveguide 2 is dimensioned below cut-off for all higher modes. The energy launched by antenna 8 is received by the output antenna

probes 9 and 9a which are orthogonally located with respect to each other to receive the radiations emitted by said input antenna 8. The ends 16 and 15 of waveguide 2 are at ground potential and situated respectively behind the input and output antennas.

The phase rotation of the output voltage from the probes 9 and 9a, when receiving a circularly polarised wave is equal to the angle of rotation of the antenna 8 about the axis of the waveguide 2. The output amplitude will be equal to the input amplitude and there will be no phase shift errors, if the ends are perfectly matched.

The dimensions and spacing of spiral antenna 8 with respect to the end 16 of the waveguide 2 are so selected as to obtain a polarisation as nearly circular as possible and a good impedance match of the coaxial line. We have found that the preferred spacing should be substantially one quarter wavelength at the operating frequency.

One form of spiral antenna which has been found satisfactory for frequencies near 9375 MC using a 50-ohm coaxial transmission line for input and output connections is an antenna composed of a dielectric disc 10, 17/16ths of an inch in diameter and 1/16th of an inch thick, on which is mounted a spiral ribbon-like conductor 7, to which shaft 4 is connected. The spiral winding 7 is fixed firmly, but not necessarily flush with the surface of the dielectric disc 10. The energy received by pickup probes 9 and 9a which are orthogonally located with respect to each other is supplied to the output connectors 13 and 14. The outer conductors 17 and 20 of the output connectors 13 and 14 are coupled to the waveguide 2. Input antenna 8 and pickup probes 9 and 9a are spaced approximately 3 inches apart. Less spacing results in direct coupling between the antennas and therefore introduces errors.

Referring to Fig. 3, an alternative embodiment of the output end of a phase shifter in accordance with this invention is shown comprising a spiral receiving antenna 21 substantially identical with input antenna 8, which is used to pick up the circularly polarised waves launched by the transmitting antenna 8. The receiving antenna 21 is connected to a shaft 23, over which the received energy is supplied. Antenna 21 should preferably be spaced substantially one quarter wavelength from the end 22 of waveguide 22.

The bearing motor drive and antenna mounting methods are important if high rotational speeds are to be obtained. Irregular bearing surfaces result in physical unbalance, motor overload, and sudden speed changes, all of which cause phase errors. The motor drive must be constant, because a small speed drift of the driving mechanism results in large phase shift errors at high rotational speeds. To absorb variations in the speed of the motor a suitable mechanical low-pass filter 19 is connected between the shaft 4 and the motor 18.

In operation an input signal is applied from the coaxial line 1 to the input antenna 8. The antenna radiates the input signal, circularly polarised axially along the waveguide section 2, and the signal is received by the pickup probes 9 and 9a for propagation over the output coaxial lines 13 and 14. The pickup probes 9 and 9a are maintained in a fixed position while the antenna 8 is rotated by shaft 4. By controlling the rotation of antenna 8 a phase advance or retardation is obtainable at the output couplers relative to the input signal.

Where the waveguide 2 is made of a solid cylindrical wall, a substantially linear phase shift is obtained except for two points 180° apart in the angular setting of the phase shifter. This discontinuity at these two points is relatively sharply defined and was discovered to be caused by a resonance of the circular polarisation H_{11} mode which occurs in the opposite sense to the main or desired circularly polarised H_{11} mode for which the unit is designed. This sharp discontinuity, while not troublesome for many phase shift uses, may be substantially eliminated by suppression. Various arrangements may be provided for effecting this suppression, such as using impedance grids, or a matching stub in such a manner as to "match out" the discontinuity in the phase shifter network. When receiving antenna 21 is used, the end 22 of waveguide 2 may be recessed as indicated at 24 to improve the impedance match of the phase shifter.

What we claim is:—

1. An electrical phase-shifter comprising a substantially closed hollow waveguide-section enclosing near one end an antenna consisting of a spiral conductor arranged with its plane normal to the axis of the waveguide-section, and near the other end means for receiving circularly polarised waves radiated by the said antenna and further comprising means for rotating the said spiral conductor about the said axis.

2. A phase-shifter according to claim 1 in which the said spiral conductor is in the form of metal ribbon wound with its major faces normal to the said axis.

3. A phase-shifter according to claim 1 or 2 in which the said waveguide-section is cylindrical in form and is provided with a coaxial input connector having a hollow inner conductor arranged coaxially with the waveguide section comprising a metal shaft mechanically and electrically connected to the said spiral conductor and passing coaxially through the said inner conductor, and means for rotating the said shaft.

4. A phase-shifter according to claim 1, 2 or 3 in which the said means for receiving comprises two fixed straight probe antennas arranged normally to the said axis and ortho-

gonally to one another.

5. A phase-shifter according to claim 1, 2 or 3 in which the said means for receiving comprises a fixed spiral antenna arranged with its plane normal to the said axis.

6. An electrical phase-shifter substantially as described with reference to Figs. 1 and 2 of the accompanying drawing.

7. A phase-shifter according to claim 6 modified substantially in the manner described with reference to Fig. 3 of the accompanying drawing.

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781,672 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

FIG. 1.

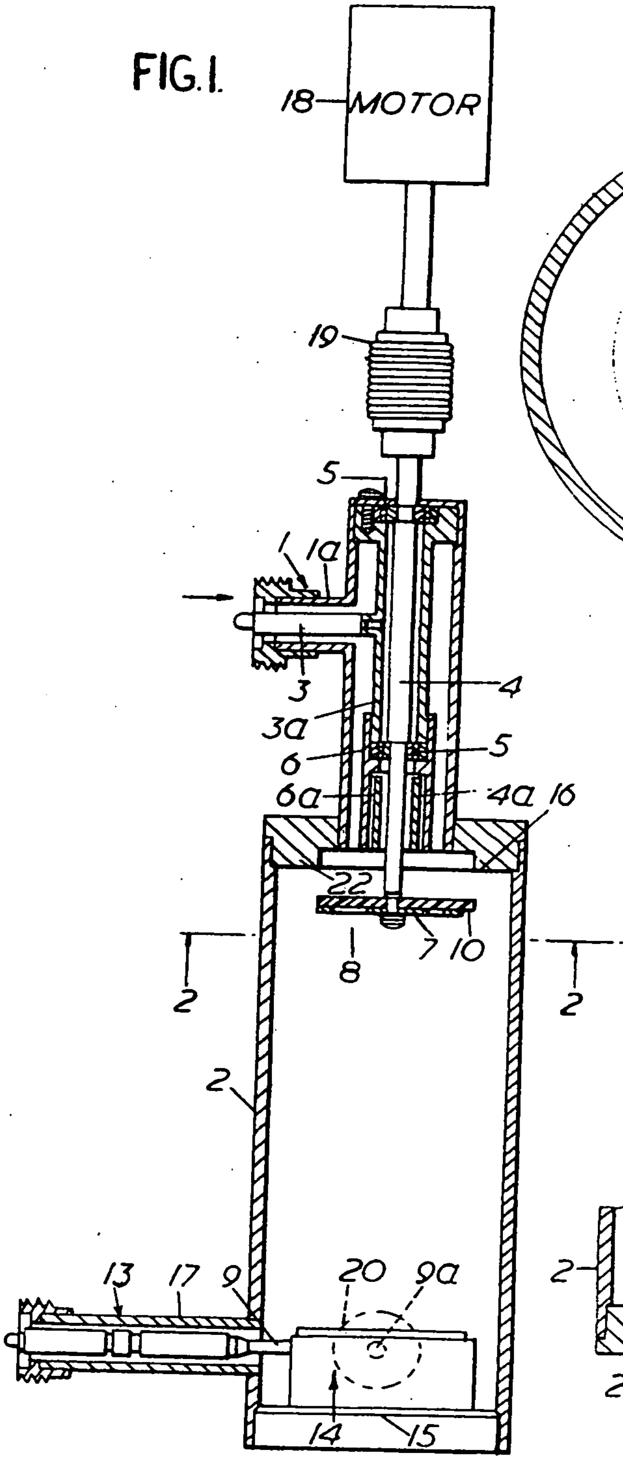

FIG. 2.

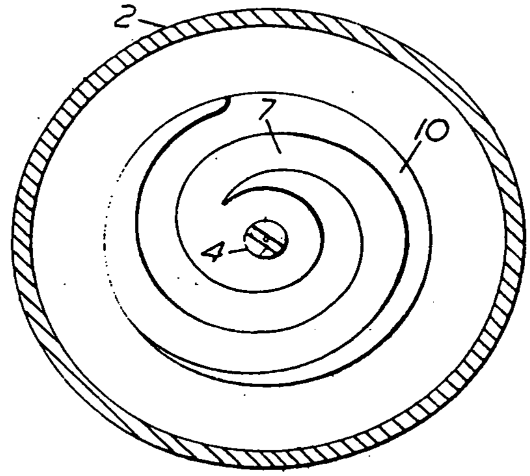

FIG. 3.